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POROSITY AND WATER ABSORPTION OF FOREST SOILS (1)

By John T. Auten, Silviculturist

The protective influence that forests exert on soil conservation and erosion control is generally recognized, but the relationships between forest litter and soil density, porosity, and water absorptive capacity have been less clearly understood. The changes in soil structure and site productivity that take place after transition from forest to field conditions, and the influence of these changes on tree regeneration and growth, have been little appreciated by those engaged in reforesting waste lands.

To arrive at a better understanding of the relation of soil to the problems of forestry and to determine the influence of forest cover and forest litter, a series of studies has been undertaken, out of which the study of soil porosity and capacity for water absorption was chosen for immediate investigation because of its important bearing on the problems of erosion, flood control, and water conservation, as well as its relation to the successful establishment and maintenance of forest plantations. To determine the contrasting conditions of forest and field soils, a comparison of these characteristics was made in four distinct phases, as follows: (1) old-growth forest soil with open-field soil; (2) second-growth forest soil with open-field soil; (3) grazed with ungrazed second-growth forest soil; (4) forest-plantation soil with open-field soil.

Porosity of Forest and Open Field Soil. From among the very few timber stands in the Central States undisturbed by cutting, grazing, or recent fire, 22 old-growth forest areas were carefully selected in Ohio, Indiana, Michigan, and Illinois. Adjacent field sites were chosen as near the forest as possible, at the same elevation, with soils originally of the same type. Some of the fields had been recently cultivated, others were in sod. Every effort was made to secure paired areas where the change of soil conditions from forest to field could be compared fairly.

Twenty soil tests for apparent specific gravity, or air-dry weight divided by a constant volume, were taken on each area, 10 in the forest and 10 in the adjacent field. Soil samples were taken to a nine-inch depth. All surface litter and duff were removed from the forest site in order that the comparisons might be made purely on the basis of mineral soil. The field soil did not, of course, have the surface organic horizon. Averages of real

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(1) This STATION NOTE summarizes an 18-page illustrated article which appeared in the Journal of Agricultural Research, U.S.D.A., June 1, 1933, (Vol. 46, No. 11, pages 997-1014). Because of the limited distribution of this article, a mimeographed summary has been prepared to meet further requests for information.

specific gravities for forest and field soils indicated only very slight differences: 2.613 ± 0.0032 (standard deviation, 0.020) for forest soils and 2.623 ± 0.007 (standard deviation, 0.044) for field soils. The similarity of these figures eliminates the possibility of the difference in forest and field soil density being caused by difference in the actual weight of the soil material.

When the specific gravities of the different soils were tabulated and averaged, it was found that, in the upper 9 inches the average field soil was 15.3 per cent heavier than the average forest soil. In other words, the upper 9-inch layer of the average field soil was 15 per cent more dense and therefore relatively less porous than the average old-growth forest soil. The difference may be as much as 30 per cent in certain areas. Similar tests conducted in 36 second-growth forest areas in Ohio gave practically the same results. Apparently soil porosity is not lost by cutting provided that forest cover, forest litter, and natural forest conditions are maintained.

The question naturally arises, to what depth does the greater porosity of forest soils extend? Does the difference occur only at the immediate surface or is it distributed throughout the entire 9-inch profile? This point is significant in the survival of tree seedlings, because if the porosity extends to any considerable depth, seedling roots will be able to penetrate much easier and the percentage of survival will be greater. The important question as to difference in water-holding capacities of forested and cultivated areas would be clarified by knowledge of the extent of looseness below the surface.

To settle this question, specific-gravity tests were made in each of three successive 3-inch soil layers in old-growth woods and adjacent field sites. The upper 3 inches of the average field soil was found to be 43.13 per cent heavier than the similar soil layer of the average old-growth forest site adjacent. This difference is based entirely on the mineral soil below the litter and duff accumulation. Similarly, the average density of the 3 to 6-inch soil layer was 12.29 per cent greater in the case of field soils. In the 6 to 9-inch layer the difference in density was negligible.

From these comparisons it may be seen that the greatest difference in density between old-growth woods soil and field soil is in the upper 6 inches. But although the lower layer shows no difference by apparent specific gravity measurements, water-absorption experiments show that the lower layer absorbs water much more rapidly in woods than in field soil.

Water Absorption of Forest Soils. As a corollary to the measurements of apparent specific gravity, a series of water absorption tests were made in old-growth forest areas and adjacent fields. Brass tubes, 2 inches in diameter and 12 inches long, were forced into the soil to a constant depth of 3 cm. This depth proved sufficient to insure that the water would not flow up around the end. The rate of water absorption from these tubes was measured at the depths of 1, 3, and 8 inches. At the first depth, the litter or duff layer was removed. At the second or 3-inch depth, a trench 2 inches deep was dug before the tubes were inserted. At the lower depth, a trench 7 inches deep was dug. This procedure placed the bottoms of the brass tubes approximately 1, 3, and 8 inches below the soil surface.

The relative rates of water absorption in forest and field soils strengthen the conclusion drawn from the density measurements, that forest soils are more porous than field soils. At the 1-inch depth the forest soils absorbed water 50 times as readily as did the field soils; at the 3-inch depth the absorption by forest soils was nearly 15 times as rapid; even at the 8-inch depth, where no difference in soil density was apparent, absorption by forest soils was more than twice that of the field soils. Although these figures are only relative, they clearly indicate the tremendous water-holding capacity of a forested area in contrast to the resistance to absorption and therefore the rapid run-off from cleared lands.

Soil Porosity of Grazed and Ungrazed Woods. Nine second-growth forest sites were selected as typical of grazed and ungrazed woodlands. The grazed areas were in the last stages of forest degradation with only a few old trees, no reproduction, and a ground cover of weeds, grass, and sod. The upper 9-inch layer of the average grazed woodland soil was found to be 15 per cent heavier than the corresponding soil section in an adjacent similar ungrazed area. Excessive pasturing not only prevents tree reproduction but also makes forest exhaustion inevitable through compaction of the soil. The grazed soil is harder, holds less moisture, has poorer aeration, and its general tilth is much deteriorated.

Soil Porosity in Forest Plantations. The final phase of the soil porosity study deals with forest plantation sites. Does soil porosity return to old fields after planting? Thirteen forest plantations from 12 to 60 years of age were measured for soil porosity and compared with adjacent field sites. The difference in weight of the upper 9-inch layers showed that the field soil averaged 13.6 per cent heavier than similar layers of adjacent plantation soil. This difference may be considered to represent a gain in porosity since planting. Field observations show that as soon as a litter is established under a planted stand of trees the soil becomes more porous. The observation was also made that the soil of coniferous plantations gained more in porosity in a given time than did that of hardwoods.

Tests in forest plantation and adjacent field soils also demonstrated that plantation soils have a much greater water absorption capacity. The average rate for the plantation sites at the 1-inch depth was 107 cc per minute compared with 8 cc for the field site. At the 8-inch depth, the averages were 13 and 3 cc per minute for the plantation and field sites respectively. These differences in absorption capacity are in line with the density differences recorded and represent a gain in soil porosity for the plantation since planting.

Functions of Forest Litter. The influence of forest on soil is inseparably connected with forest litter, and the proper production and retention of adequate quantities and kinds of forest litter is dependent upon good silvicultural practice. In the Central States region the accumulation of litter is seldom more than 1 inch in depth. The leaf fall decomposes rapidly and adds its fertility to the soil. The forest litter is, however, of great importance in this region even though it does not accumulate to a great depth. It serves as an absorbent, acts as a mulch or insulation against rapid evaporation, prevents compaction of surface soil by impact of rain, decomposes and furnishes plant food, and serves as a medium for microbiological activities.

Structure of forest soil has been developed through long periods of time. Root penetration, expansion and contraction with changes in temperature and moisture content, and activities of worms, insects, and animals, tend to make soil porous. The forest is a builder and a preserver of soil porosity. The penetration of roots and their eventual decay leave the soil interpenetrated with tubelike cavities. The process of cropping, on the other hand, ultimately decreases soil porosity and favors erosion. The porosity preserved in forest soils by the covering of litter is largely lost in field soils by impact of rain and by the silting and illuviating action of percolating waters.

When the Central States region was settled originally, both good and poor lands were cleared and cultivated. The accumulation of organic matter in the form of incorporated and unincorporated forest litter afforded a temporary supply of plant food, and even the poorer, shallow soils produced well for a time. Then this food supply became exhausted and the land ceased to yield a reasonable return for its cultivation. As the organic matter was oxidized, plant food leached away, and the top soil eroded, the land became increasingly unproductive. The impoverishment under agricultural use of originally fertile forest soil became a major factor in the growth of land abandonment.

Forest Management. Virgin old-growth forests, except as a valuable means of interpreting optimum site conditions, are of no concern in the Central States region. The virgin woods are gone; only second-growth and abandoned fields remain. In the case of second-growth woodlands, careful cutting and consequent opening up of the stand does not destroy soil porosity, provided the forest cover is quickly reestablished, and the litter is not destroyed by fire or grazing. To a great extent soil porosity is an indication of site productivity.

The millions of acres of submarginal and abandoned lands suffering from soil erosion represent a problem of great concern in the Central States. Most of this area was once forested with hardwoods; now that its fertility is largely exhausted an extensive reforestation program is an essential measure of land use planning. The rule in the past on such lands has been to plant the species which formerly grew there naturally or to trust to nature to reseed the area, without realization that the abandoned and deteriorated field soil is usually incapable of permitting the reestablishment of the original tree species. Great difficulty has been experienced in getting hardwood plantations established on such lands; coniferous species, especially the yellow pines, are as a rule more successful. Hardwoods, with the possible exception of black locust, are not so able to survive the adverse conditions that occur in worn-out soil. Mixed planting of locust and native yellow pines is recommended.